A year in the life of a large-scale experimental distributed system: usage of the Grid'5000 platform in 2007

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INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

A year in the life of a large-scale experimental distributed system: usage of the Grid'5000 platform in 2007

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A year in the life of a large-scale experimental distributed system: usage of the Grid'5000 platform in 2007

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Abstract: This report presents the usage results of Grid'5000 over year 2007. Usage of the main operationnal Grid'5000 sites (Bordeaux, Lille, Lyon, Nancy, Orsay, Rennes, Sophia-Antipolis, Toulouse) is presented and analyzed.

Key-words: Large scale distributed system, usage, Grid'5000

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Une année dans la vie d'un système distribué expérimental à grande échelle : l'utilisation de la plate-forme Grid'5000 en 2007

Résumé : Ce rapport présente les résultats d'utilisation de la plateforme expérimentale Grid'5000 pendant l'année 2007. L'usage des principaux sites opérationnels de Grid'5000 (Bordeaux, Lille, Lyon, Nancy, Orsay, Rennes, Sophia-Antipolis, Toulouse) est présenté et analysé.

Mots-clés : Système distribué à grande échelle, usage, Grid'5000

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1 Introduction

Some previous work on operational Grids [IDE+06] show that grids are not utilized at their full capacity. We focus on the utilization of a large-scale experimental distributed system by relying on the case study of Grid'5000[Cea05][1], a French experimental Grid. We collected and analyzed the logs of the Grid'5000 platform for a full year of usage (2007). We present the main statistics observed for each site and some specific and representative computing nodes. A special analysis is dedicated to the grid usage of this experimental platform. This usage analysis has been used in some works on energy-efficient experimental distributed infrastructures [OLG08a, OLG08b].

This paper briefly presents the Grid'5000 experimental platform and the followed methodology in Section 2. The usage statistics are then presented for each Grid'5000 site (Section 3) and for grid jobs (Section 4). A small conclusion in Section 5 summarizes the main observed results.

2 Definitions and Methodology

2.1 Grid'5000: a Large-Scale Experimental Distributed System

The Grid'5000 platform is an experimental testbed dedicated for research in computer science, made up of more than 3400 processors geographically distributed on 9 sites in France (see Fig. 1). This platform can be defined as a highly reconfigurable, controllable, and monitorable experimental large-scale distributed system.

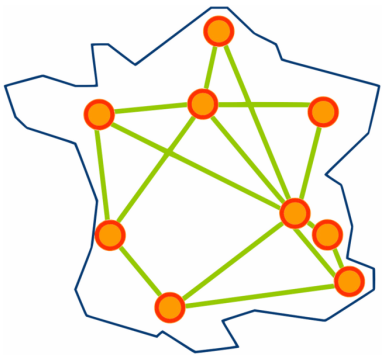

Figure 1: The Grid'5000 map

The utilization of Grid'5000 is very specific. Each user can reserve (in advance) some computing nodes. During its reservation time, the user can be root on his reserved nodes and he can deploy his own system images, collect data,

[1]Some experiments of this article were performed on the Grid'5000 platform, an initiative from the French Ministry of Research through the ACI GRID incentive action, INRIA, CNRS and RENATER and other contributing partners (http://www.grid5000.fr). This research is supported by the GREEN-NET INRIA Cooperative Research Action: http://www.ens-lyon.fr/LIP/RESO/Projects/GREEN-NET/

launch applciations, reboot, and so on. The nodes are entirely dedicated to the user during his reservation.

2.2 Experiment Methodology

The user gives the resource manager (at least) a start time, a duration, and the number of required resources. These characteristics define the job (a reservation). The resource manager is in charge of the job's acceptance. It verifies if that job is compatible with previously accepted jobs and, if it is, it gives a job id to the user.

When a resource is not available for the user, it can be in different states:

- **dead**: the resource is down (due to a component failure for example);
- **suspected**: the resource does not work properly;
- **absent**: the resource is not available for the user (not physically present, still in the box for example).

Moreover, the platform has changed between the beginning and the end of the measurements. For that reason, we present the results as percentages of the platform's capacity at the time of measurement (100% at a given time does not represent the same number of resources as 100% at another time).

In order to obtain the utilization traces, we have used a history function provided by OAR[2] [CCG+05] called *oarstat*. This function provides the user with all the events that occur during a time period. An event can be a job or a problem on a resource (it is dead, absent or suspected) for a given period. Our goal is to obtain a detailed overview of the usage of an experimental grid.

3 Grid'5000's usage per site

3.1 Overall statistics

We have made some statistics per site and some more for grid jobs (the jobs which take place on several sites at the same time). The studied period starts on the 1st January 2007 (at 00:00:00) and finishes on the 6th January 2008 (at 23:59:59).

As the platform varies during time (node additions), the number of resources also varies depending on the time (see Figure 2). We have taken this into account to calculate the different statistics. So the maximal number of resources refers to the number of resources at the end of the experiments.

[2]OAR is a resource manager (or batch scheduler) for large clusters.(http://oar.imag.fr/index.html)

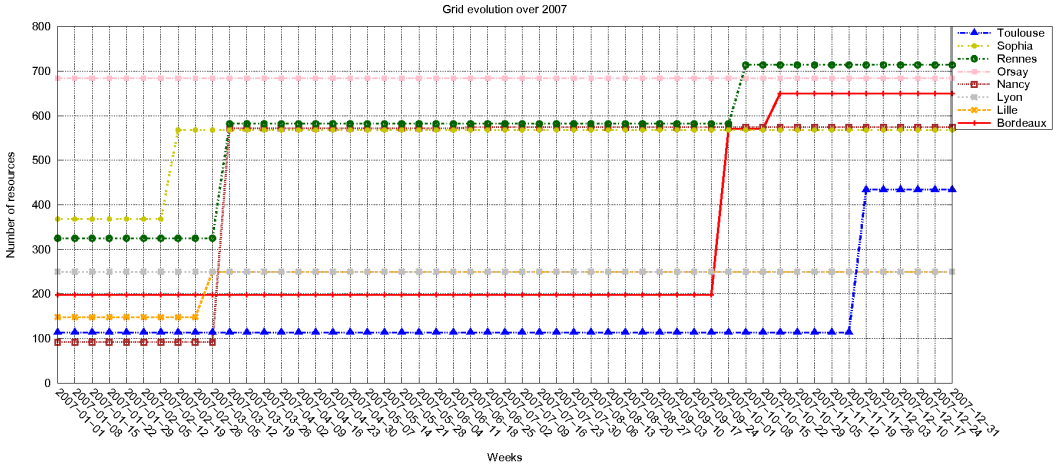

Figure 2: Platform evolution in terms of number of resource (cores) over year 2007

3.2 Results per Grid'5000 site

For each site, we provide several values and figures which represent the global usage of the site. All the times are given in seconds. A resource is a core and a job is actually a reservation.

We have split the proposed statistics in three categories:

- the "platform and resources" part which lists the available number of resources and some statistics on the resources' states. We also compute the real work time of the Grid'5000 site. The "real" percentage of work time is calculated without taking into account dead time or absent time (i.e. work time over total time minus dead time and absent time for all the resources).
- the "jobs" part proposes some statistics on the number of submitted jobs (reservations), the mean time and mean number of resources per job, and the maximal duration of a job on a site. We also list the number of reservations used for deploying system images (*deploy jobs*)
- the "users" section contains the number of users and the impact of users from other Grid'5000 sites. The percentage of users coming from other sites does not take into account any consideration of proportionality in terms of jobs. It is just the number of users coming from other sites over the total number of users (each user is counted once).

For each site, we provide four diagrams. The first one represents the weekly repartition in time of the resources between the different states: in red when some cores are dead (*Dead* state), in orange when they are suspected (*Suspected* state), in yellow when they are absent (*Absent* state), in green when they are working (a job is running) (*Work* state), and in white when they are unoccupied (no job, no other state) (*Idle* state).

The two other diagrams present the weekly time repartition of two particular resources: the median and the maximal resources. The maximal resource is the resource which has the maximal work time among the resources which are present for the whole 2007 year. The median resource is a resource which is present for the whole 2007 year and is the nearest to the median value of cumulative work over the experiment's duration.

3.2.1 Usage of Grid'5000's Bordeaux site in 2007

- Platform and resources:
  - Maximal number of resources (cores): 650
  - Mean time spent in each state for all the resources, in percentage:
    - Dead: 20.78%
    - Suspected: 1.40%
    - Absent: 0.65%
    - Work: 37.55%
  - Real percentage of work time (without taking into account the time when the resources are dead or absent): 47.80%
- Jobs:
  - Number of jobs (reservations): 45775
  - Mean time of a job: 5224.59 (1 hour 27 minutes and 5 seconds)
  - Maximal duration: 454584 (5 days 6 hours 16 minutes and 24 seconds) for job number 56231
  - Mean number of resources (cores) per job: 55.50
  - Number of 'deploy' jobs: 1678 (3.67% of the jobs)
  - Percentage of jobs coming from other sites: 0.53%
- Users:
  - Number of users: 174
  - Percentage of users coming from other sites: 85.06%

 For this site, we can notice a period of more than three months during which all the resources are dead: this is due to an air-cooling problem. As the percentage of 'real' work does not take into account the dead and absent time, this dead period is not considered in this percentage.

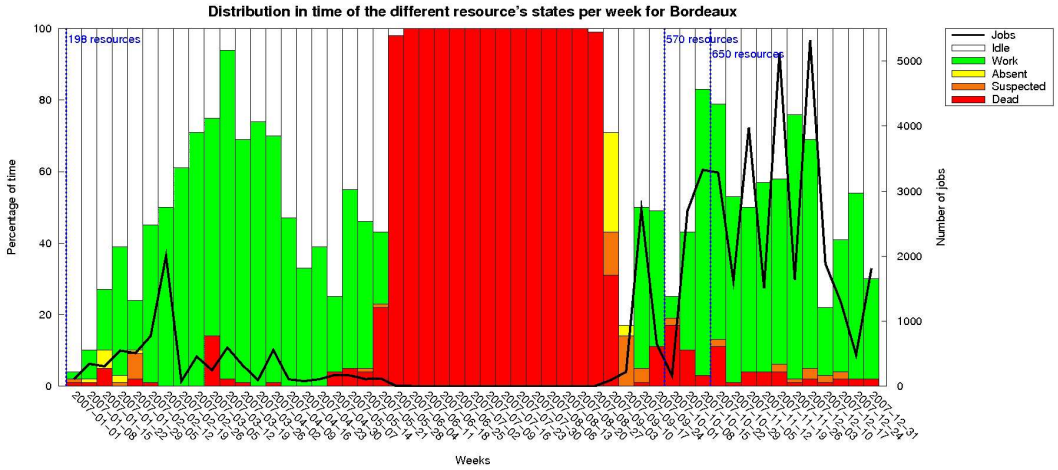

Figure 3: Global diagram with dead time for Grid'5000's Bordeaux site

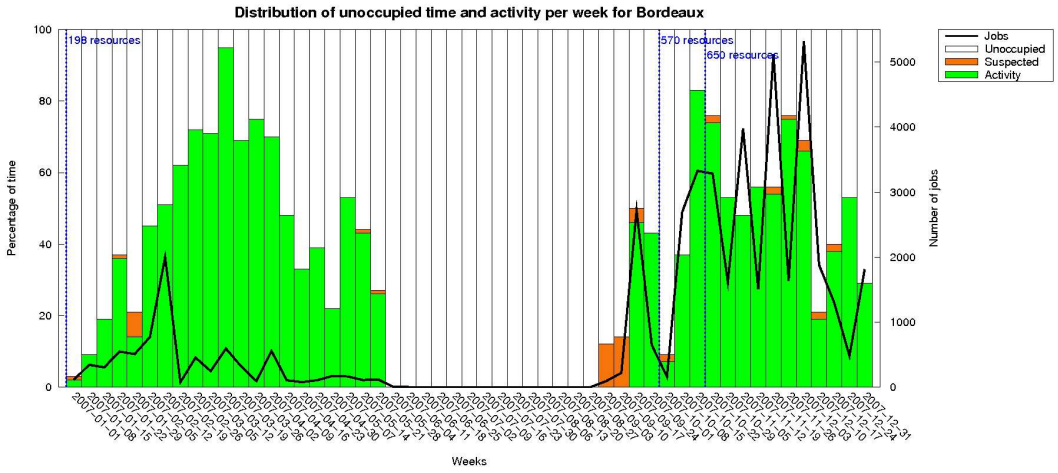

Figure 4: Global diagram without dead time for Grid'5000's Bordeaux site

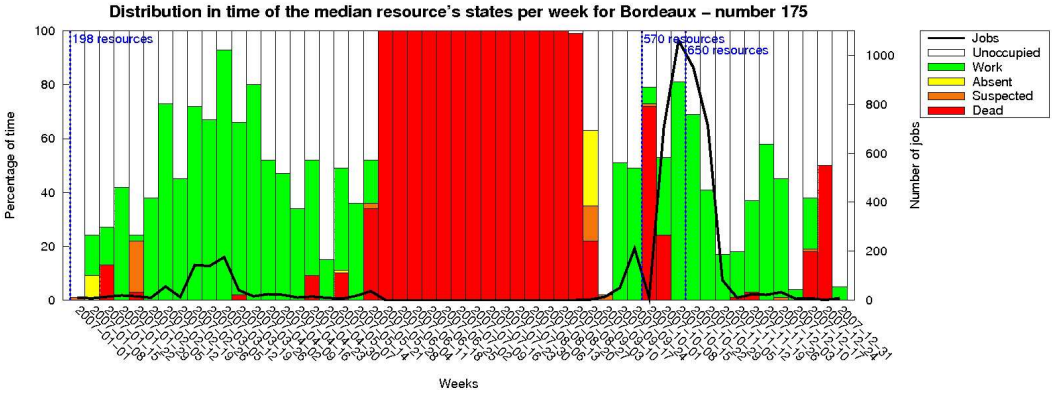

Figure 5: Median resource diagram for Grid'5000's Bordeaux site

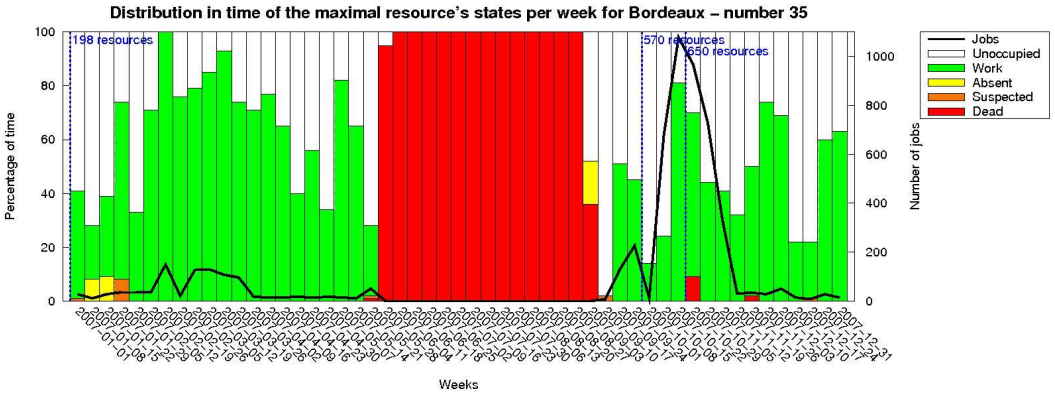

Figure 6: Maximal resource diagram for Grid'5000's Bordeaux site

3.2.2 Usage of Grid'5000's Lille site in 2007

- Platform and resources:
  - Maximal number of resources (cores): 250
  - Mean time spent in each state for all the resources, in percentage:
    - Dead: 9.30%
    - Suspected: 4.31%
    - Absent: 0.89%
    - Work: 32.73%
  - Real percentage of work time (without taking into account the time when the resources are dead or absent): 36.44%
- Jobs:
  - Number of jobs (reservations): 330694
  - Mean time of a job: 1446.13 (24 minutes and 6 seconds)
  - Maximal duration: 648019 (7 days 12 hours and 19 seconds) for job number 318486
  - Mean number of resources (cores) per job: 4.81
  - Number of 'deploy' jobs: 2172 (0.66% of the jobs)
  - Percentage of jobs coming from other sites: 0.08%
- Users:
  - Number of users: 181
  - Percentage of users coming from other sites: 74.59%

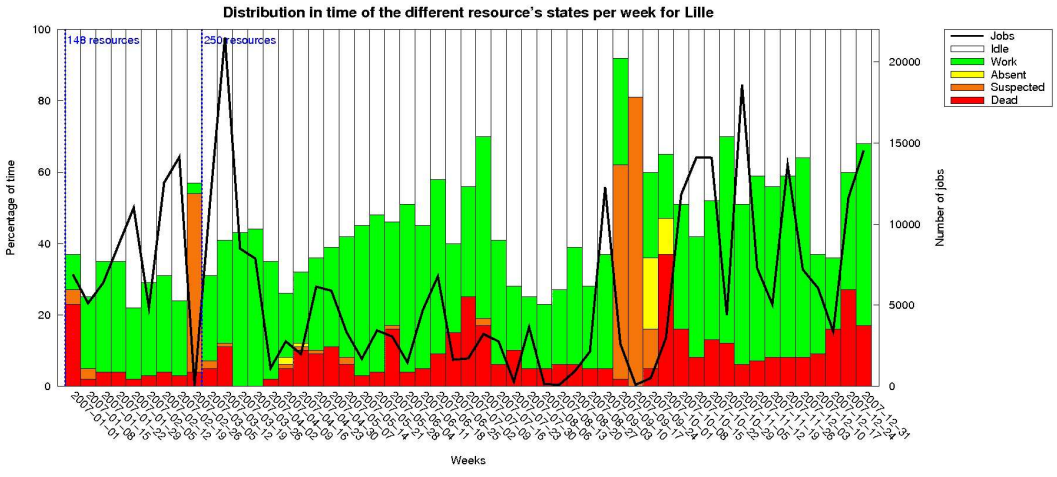

Figure 7: Global diagram with dead time for Grid'5000's Lille site

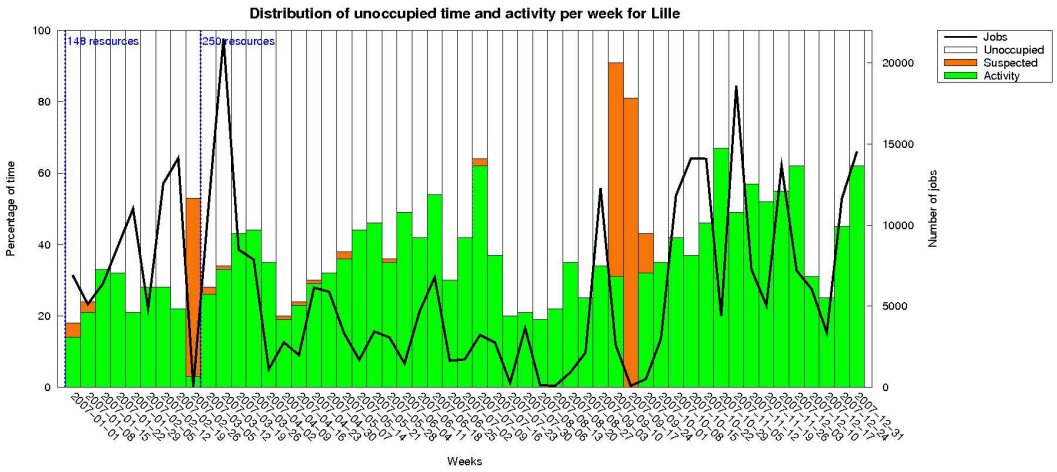

Figure 8: Global diagram without dead time for Grid'5000's Lille site

This site has got the largest number of jobs over year 2007. However, it has the smallest mean job length (less than 25 minutes): there are a lot of 'small' jobs on this site.

Also, the two resource views clearly show an important disparity between the usage of the different resources.

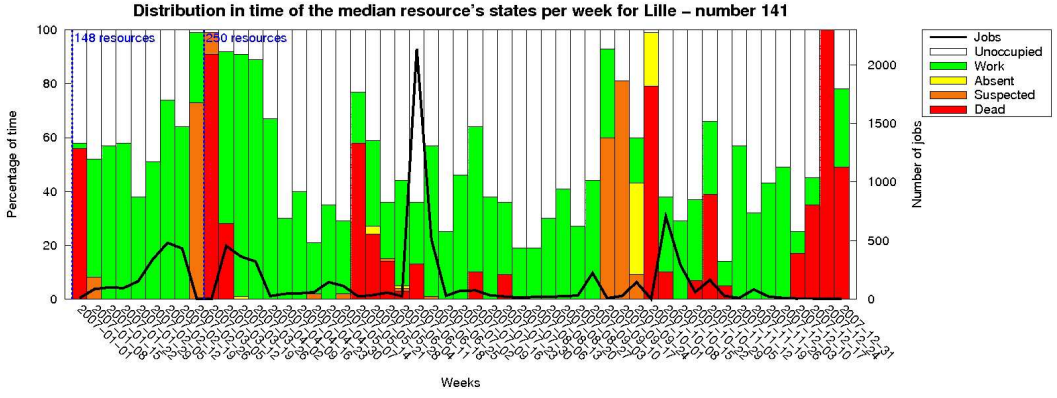

Figure 9: Median resource diagram for Grid'5000's Lille site

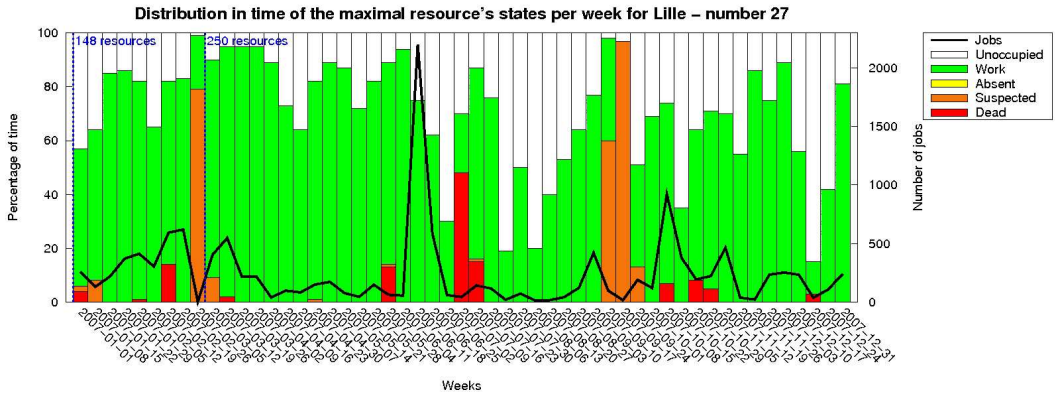

Figure 10: Maximal resource diagram for Grid'5000's Lille site

3.2.3 Usage of Grid'5000's Lyon site in 2007

- Platform and resources:
  - Maximal number of resources (cores): 322
  - Mean time spent in each state for all the resources, in percentage:
    - Dead: 13.76%
    - Suspected: 1.75%
    - Absent: 0.86%
    - Work: 39.60%
  - Real percentage of work time (without taking into account the time when the resources are dead or absent): 46.38%
- Jobs:
  - Number of jobs (reservations): 33315
  - Mean time of a job: 3246.15 (54 minutes and 6 seconds)
  - Maximal duration: 1235695 (14 days 7 hours 14 minutes and 55 seconds) for job number 48942
  - Mean number of resources (cores) per job: 41.64
  - Percentage of jobs coming from other sites: 0.74%
  - Number of 'deploy' jobs: 2690 (8.07% of the jobs)
- Users:
  - Number of users: 147
  - Percentage of users coming from other sites: 71.43%

 On the first diagram, we can see the effect of vacations: resources are less used in August, in September, and during the Christmas holidays. This is noticeable even on the most used resource.

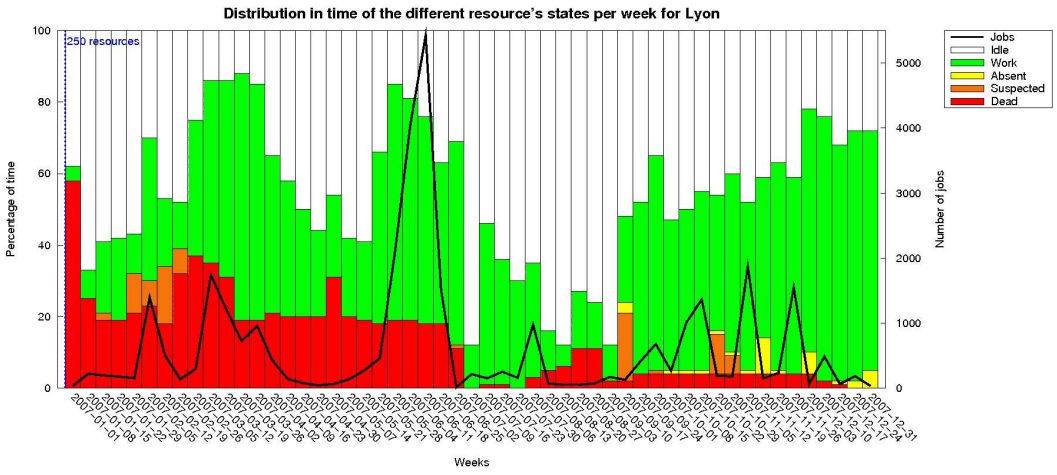

Figure 11: Global diagram with dead time for Grid'5000's Lyon site

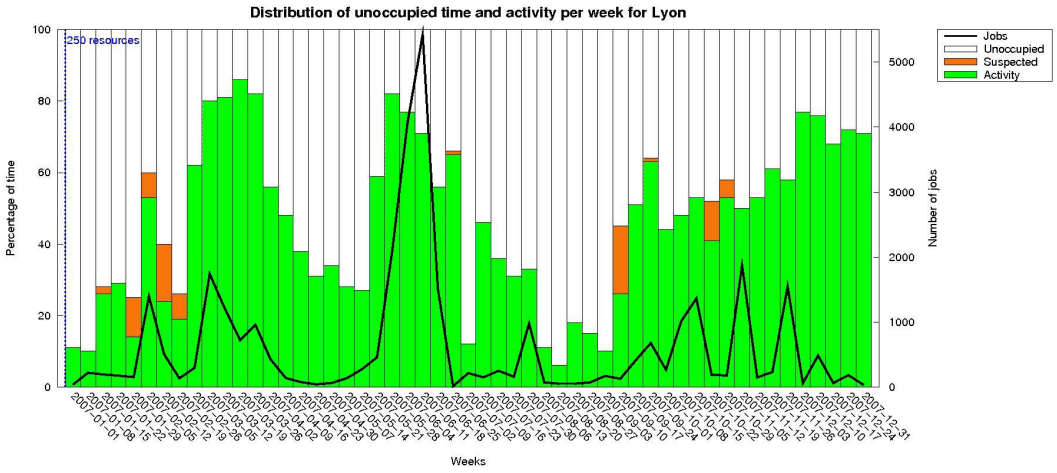

Figure 12: Global diagram without dead time for Grid'5000's Lyon site

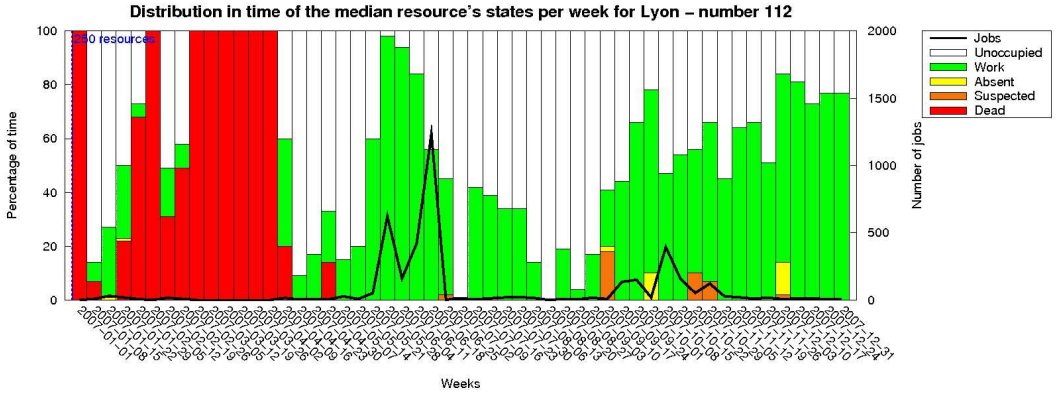

Figure 13: Median resource diagram for Grid'5000's Lyon site

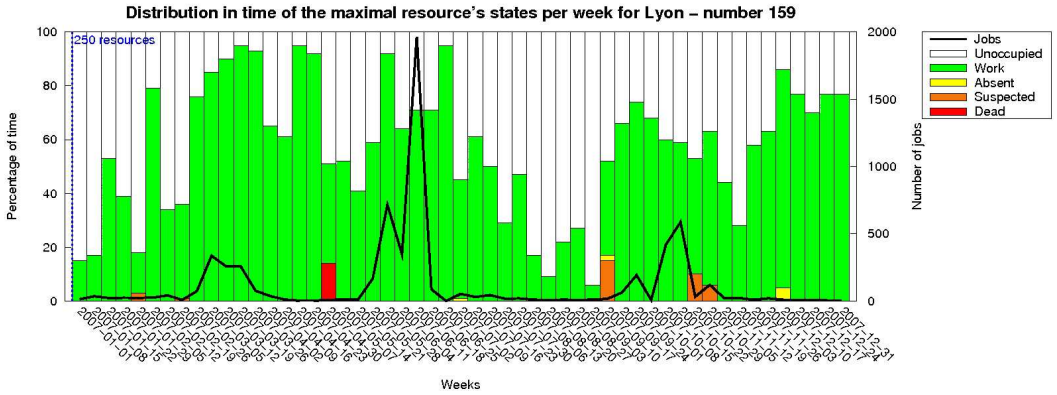

Figure 14: Maximal resource diagram for Grid'5000's Lyon site

3.2.4 Usage of Grid'5000's Nancy site in 2007

- Platform and resources:
  - Maximal number of resources (cores): 574
  - Mean time spent in each state for all the resources, in percentage:
    - Dead: 1.49%
    - Suspected: 2.76%
    - Absent: 0.15%
    - Work: 55.37%
  - Real percentage of work time (without taking into account the time when the resources are dead or absent): 56.41%
- Jobs:
  - Number of jobs (reservations): 63435
  - Mean time of a job: 19480.49 (5 hours 24 minutes and 40 seconds)
  - Maximal duration: 979934 (11 days 8 hours 12 minutes and 14 seconds) for job number 79493
  - Mean number of resources (cores) per job: 22.46
  - Percentage of jobs coming from other sites: 0.16%
  - Number of 'deploy' jobs: 2366 (3.73% of the jobs)
- Users:
  - Number of users: 154
  - Percentage of users coming from other sites: 83.12%

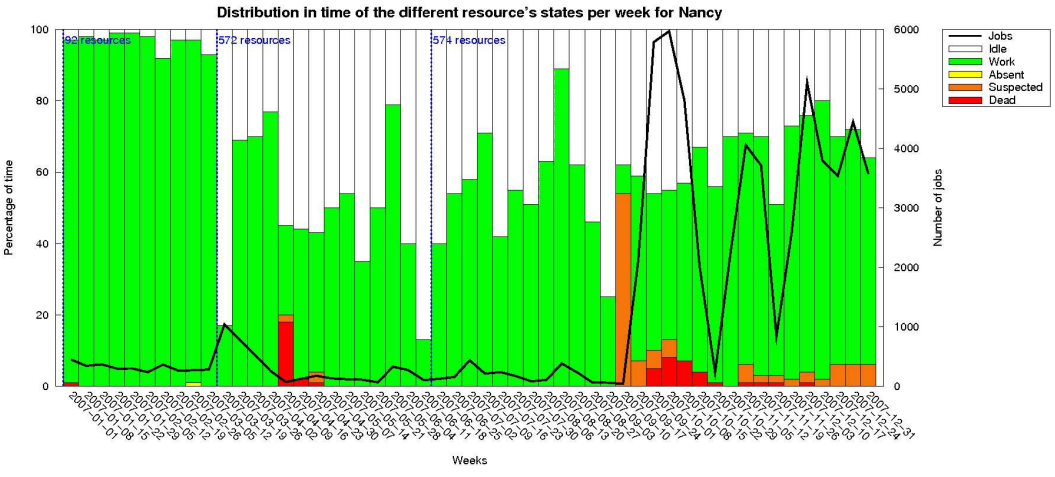

Figure 15: Global diagram with dead time for Grid'5000's Nancy site

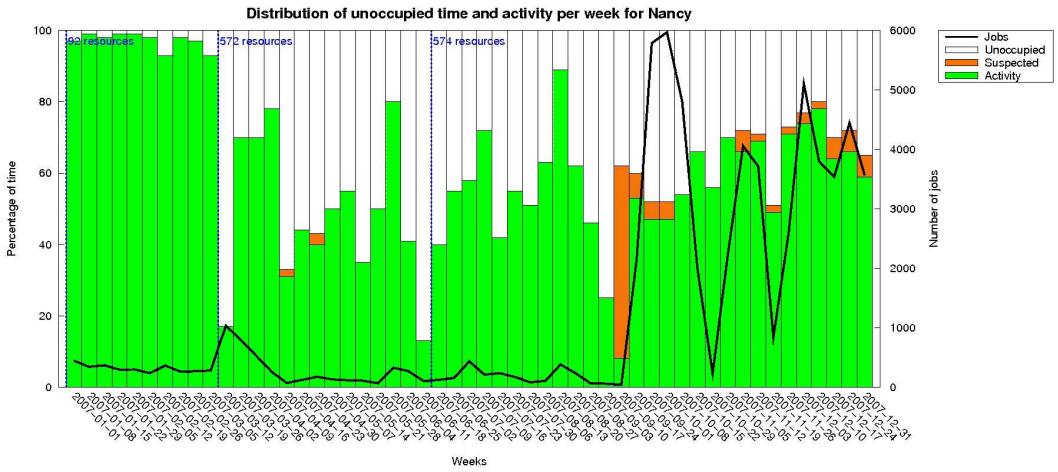

Figure 16: Global diagram without dead time for Grid'5000's Nancy site

We can observe a great stability on this site: few dead periods, a small number of jobs, but long ones (the longest mean length for a job), a high percentage of utilization, and all the resources are used as we can see on the three resource views. The workload is well balanced over the resources. We observe also two and a half months of intensive activity: from January to the middle of March, over 95% of activity most of the time.

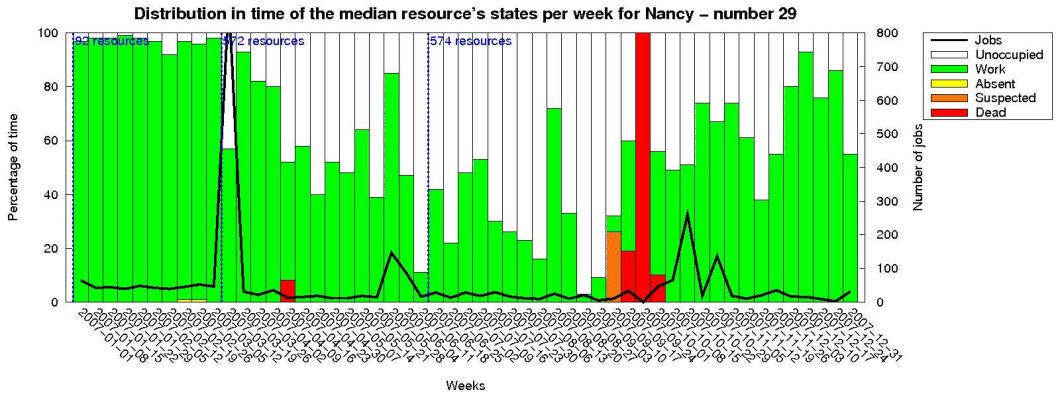

Figure 17: Median resource diagram for Grid'5000's Nancy site

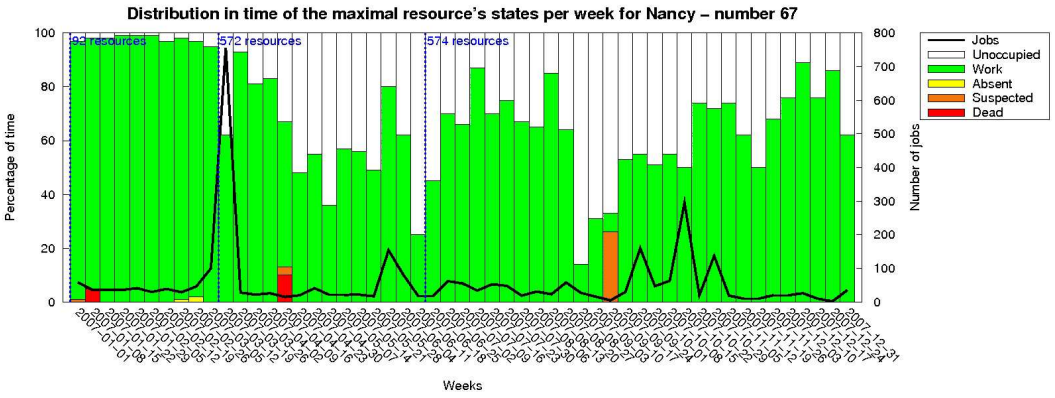

Figure 18: Maximal resource diagram for Grid'5000's Nancy site

3.2.5 Usage of Grid'5000's Orsay site in 2007

- Platform and resources:
  - Maximal number of resources (cores): 684
  - Mean time spent in each state for all the resources, in percentage:
    - Dead: 3.15%
    - Suspected: 2.69%
    - Absent: 0.99%
    - Work: 18.10%
  - Real percentage of work time (without taking into account the time when the resources are dead or absent): 18.88%
- Jobs:
  - Number of jobs (reservations): 26448
  - Mean time of a job: 4322.54 (1 hour 12 minutes and 3 seconds)
  - Maximal duration: 864008 (10 days and 8 seconds) for job number 52307
  - Mean number of resources (cores) per job: 47.45
  - Percentage of jobs coming from other sites: 0.89%
  - Number of 'deploy' jobs: 4447 (16.81% of the jobs)
- Users:
  - Number of users: 189
  - Percentage of users coming from other sites: 81.48%

 The number of jobs is comparable to the other sites, but this site has a larger number of resources, so the global percentage of usage is low.

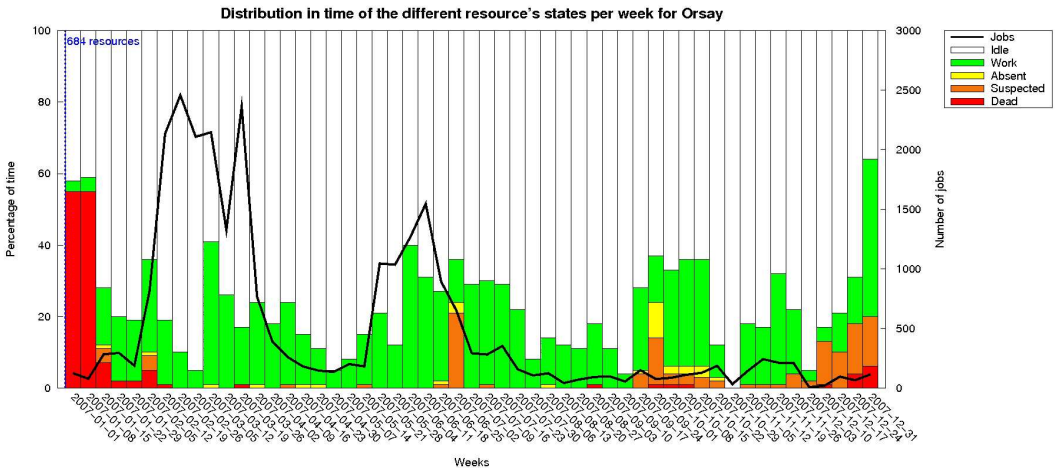

Figure 19: Global diagram with dead time for Grid'5000's Orsay site

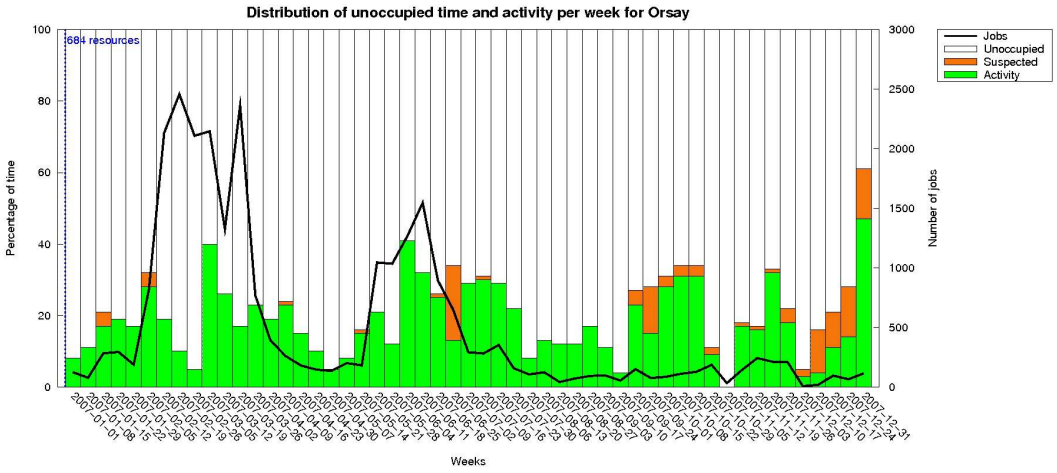

Figure 20: Global diagram without dead time for Grid'5000's Orsay site

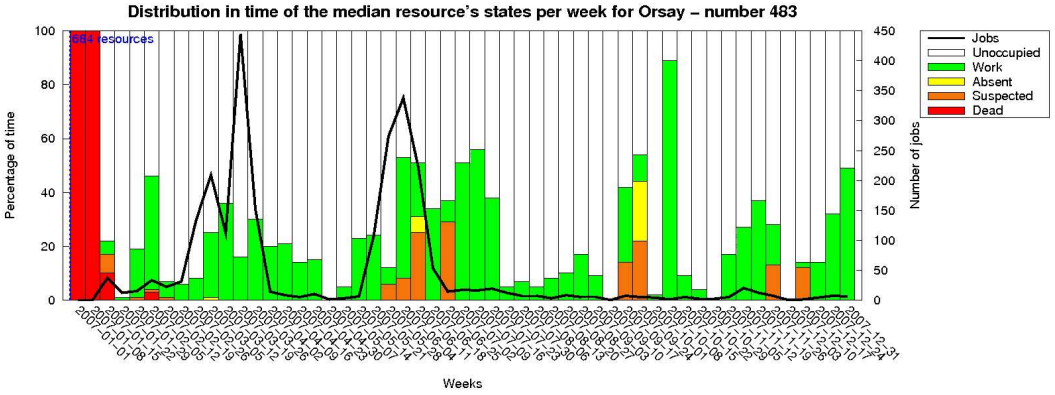

Figure 21: Median resource diagram for Grid'5000's Orsay site

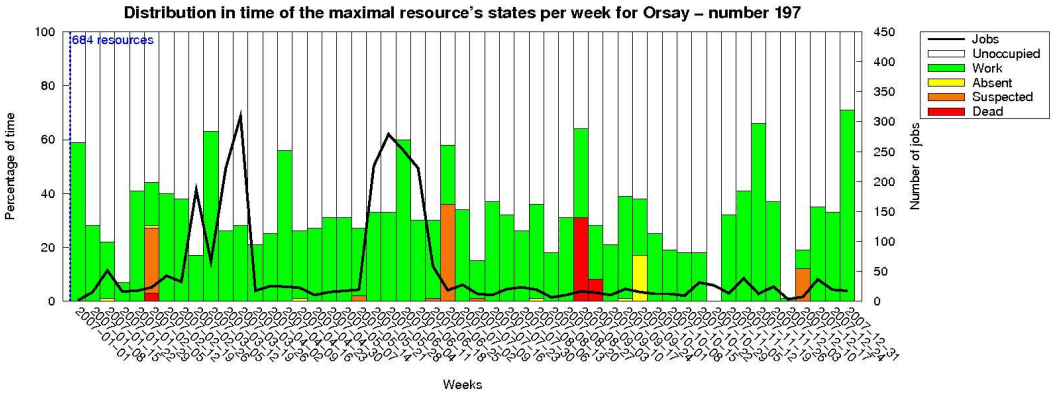

Figure 22: Maximal resource diagram for Grid'5000's Orsay site

3.2.6 Usage of Grid'5000's Rennes site in 2007

- Platform and resources:
  - Maximal number of resources (cores): 714
  - Mean time spent in each state for all the resources, in percentage:
    - Dead: 2.45%
    - Suspected: 1.09%
    - Absent: 0.87%
    - Work: 48.21%
  - Real percentage of work time (without taking into account the time when the resources are dead or absent): 49.87%
- Jobs:
  - Number of jobs (reservations): 36433
  - Mean time of a job: 7973.39 (2 hours 12 minutes and 53 seconds)
  - Maximal duration: 702342 (8 days 3 hours 5 minutes and 42 seconds) for job number 192011
  - Mean number of resources (cores) per job: 54.85
  - Percentage of jobs coming from other sites: 0.90%
  - Number of 'deploy' jobs: 3132 (8.60% of the jobs)
- Users:
  - Number of users: 194
  - Percentage of users coming from other sites: 81.96%

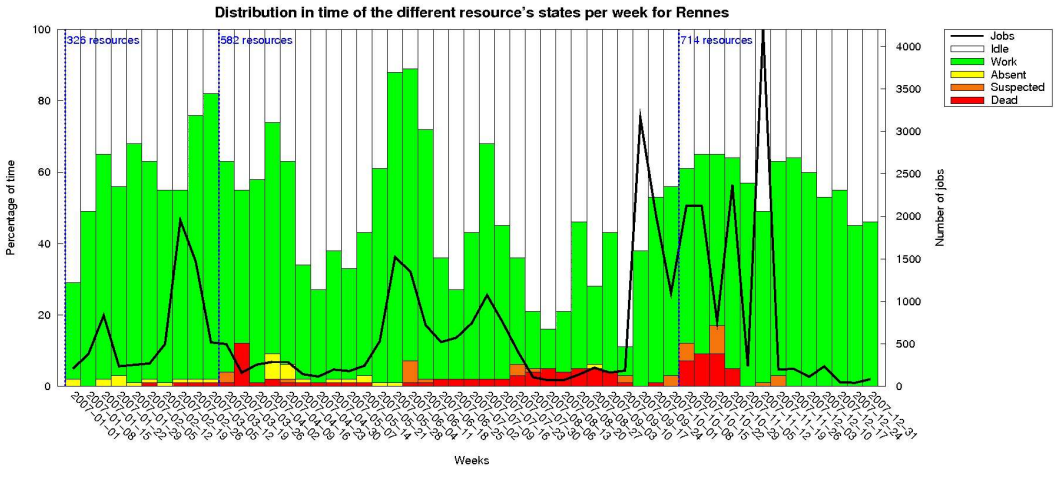

Figure 23: Global diagram with dead time for Grid'5000's Rennes site

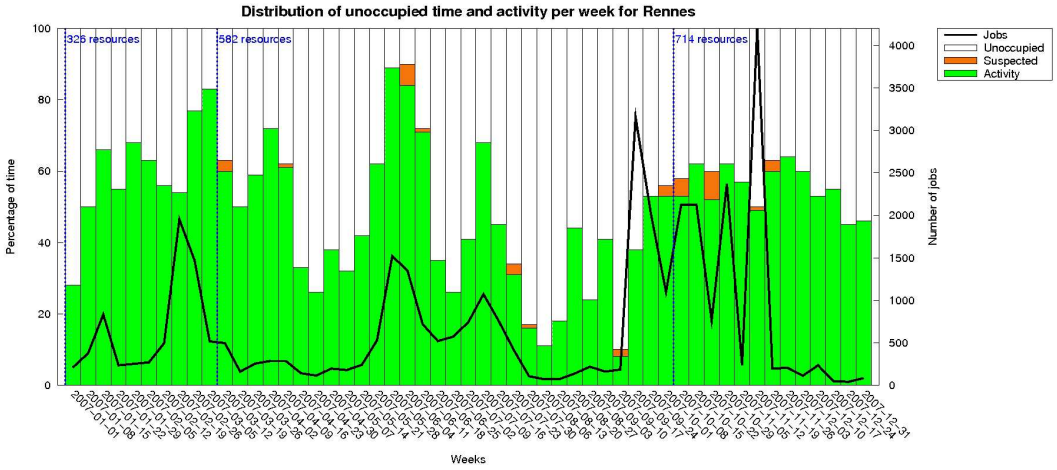

Figure 24: Global diagram without dead time for Grid'5000's Rennes site

This site is well used in terms of percentage of real work. We can notice several bursts of usage in terms of number of jobs per week, and in particular, one reaches more than 4000 jobs for one week. So there are a lot of small jobs during these periods in terms of both time and number of resources used.

We can see that after the addition of new resources in October, the median resources are not used anymore. The users reserve the new available machines instead.

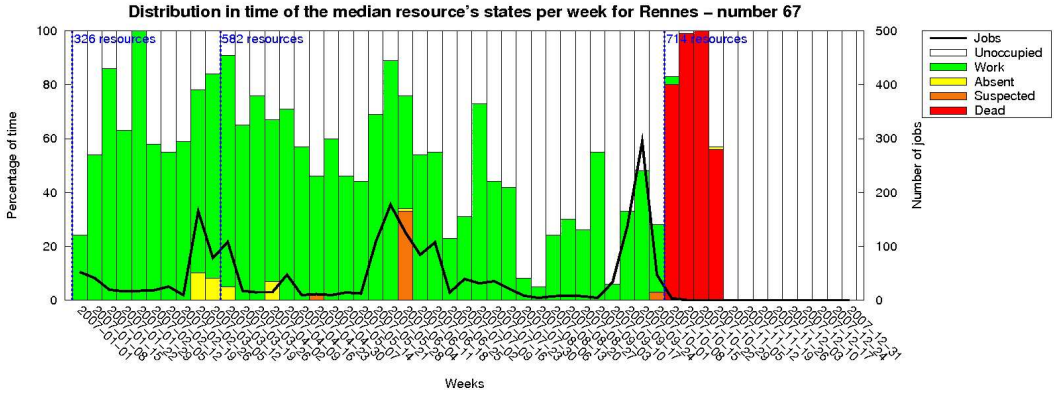

Figure 25: Median resource diagram for Grid'5000's Rennes site

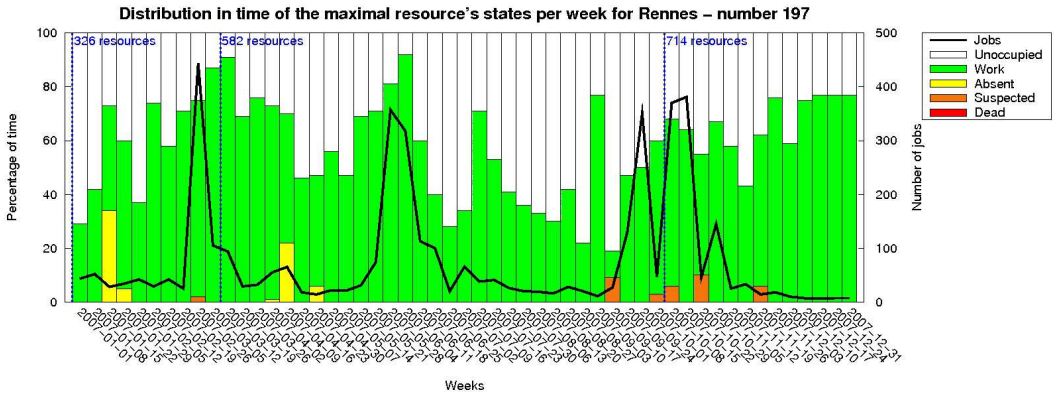

Figure 26: Maximal resource diagram for Grid'5000's Rennes site

3.2.7 Usage of Grid'5000's Sophia site in 2007

- Platform and resources:
  - Maximal number of resources (cores): 568
  - Mean time spent in each state for all the resources, in percentage:
    - Dead: 5.41%
    - Suspected: 1.19%
    - Absent: 0.13%
    - Work: 48.58%
  - Real percentage of work time (without taking into account the time when the resources are dead or absent): 51.43%
- Jobs:
  - Number of jobs (reservations): 35179
  - Mean time of a job: 4890.28 (1 hour 21 minutes and 30 seconds)
  - Maximal duration: 900021 (10 days 10 hours and 21 seconds) for job number 295097
  - Mean number of resources (cores) per job: 57.93
  - Percentage of jobs coming from other sites: 0.64%
  - Number of 'deploy' jobs: 2572 (7.31% of the jobs)
- Users:
  - Number of users: 183
  - Percentage of users coming from other sites: 81.97%

 We see on the different diagrams that there are four distinct periods of more intensive work: usage is really bursty. This is a characteristic of experimental Grids.

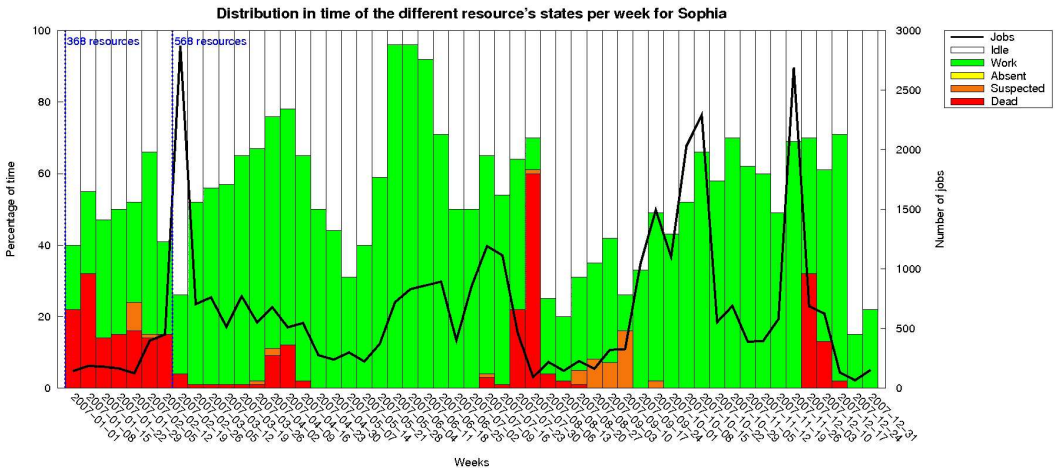

Figure 27: Global diagram with dead time for Grid'5000's Sophia site

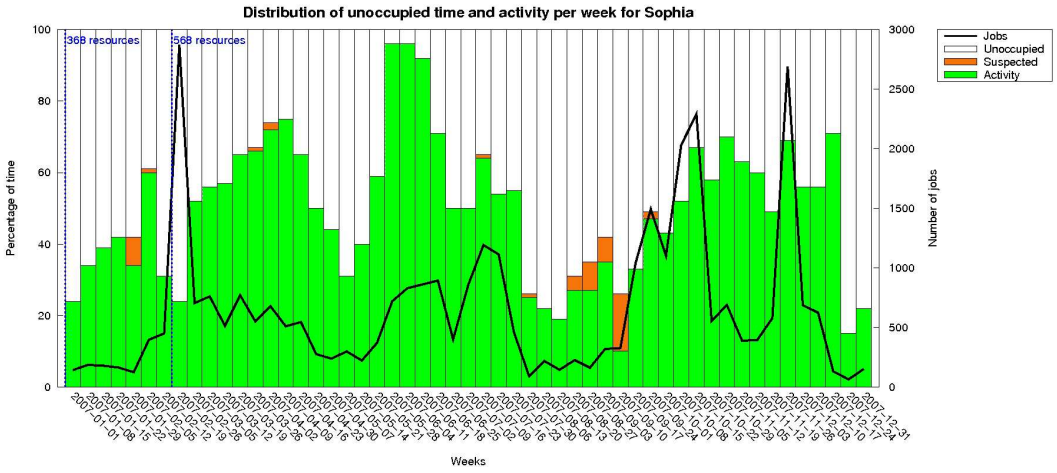

Figure 28: Global diagram without dead time for Grid'5000's Sophia site

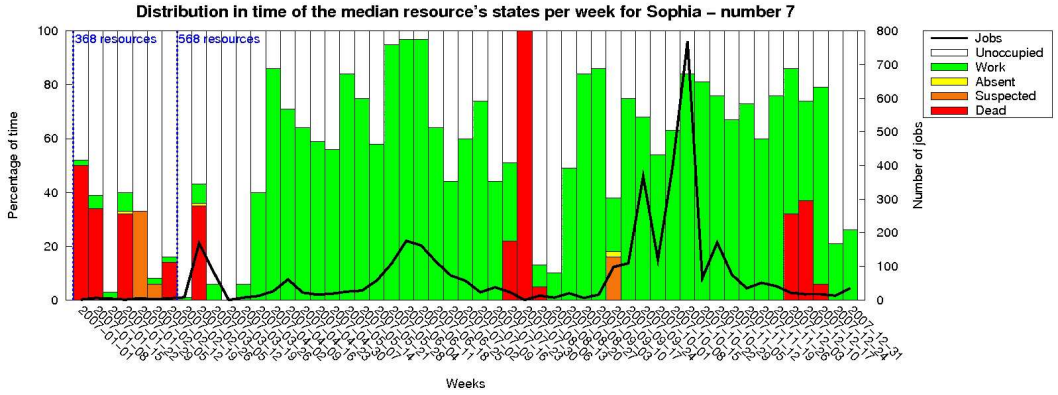

Figure 29: Median resource diagram for Grid'5000's Sophia site

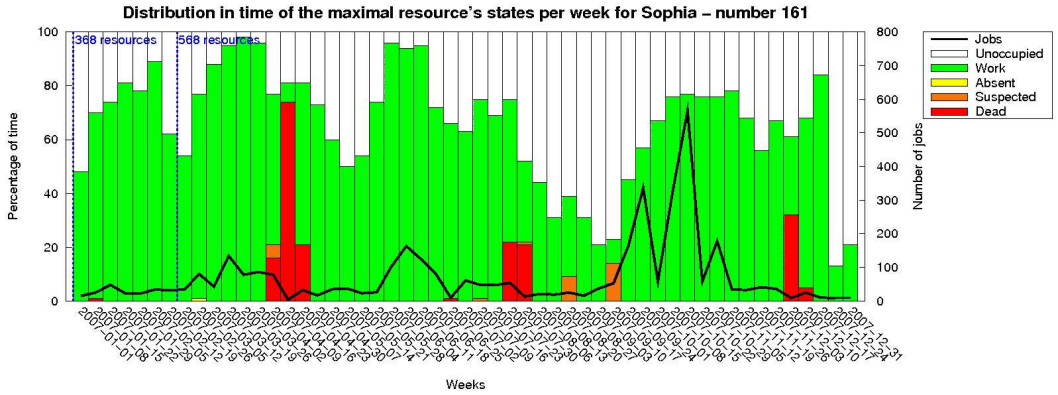

Figure 30: Maximal resource diagram for Grid'5000's Sophia site

3.2.8 Usage of Grid'5000's Toulouse site in 2007

- Platform and resources:
  - Maximal number of resources (cores): 434
  - Mean time spent in each state for all the resources, in percentage:
    - Dead: 1.38%
    - Suspected: 4.41%
    - Absent: 1.12%
    - Work: 49.30%
  - Real percentage of work time (without taking into account the time when the resources are dead or absent): 50.57%
- Jobs:
  - Number of jobs (reservations): 20832
  - Mean time of a job: 7420.07 (2 hours 3 minutes and 40 seconds)
  - Maximal duration: 955177 (11 days 1 hour 19 minutes and 37 seconds) for job number 85103
  - Mean number of resources (cores) per job: 12.89
  - Percentage of jobs coming from other sites: 0.59%
  - Number of 'deploy' jobs: 818 (3.93% of the jobs)
- Users:
  - Number of users: 161
  - Percentage of users coming from other sites: 75.78%

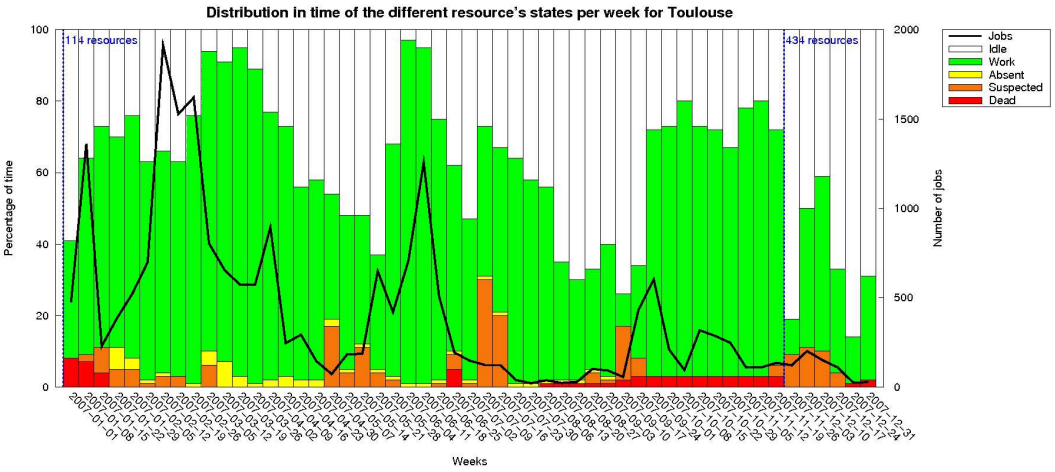

Figure 31: Global diagram with dead time for Grid'5000's Toulouse site

On this site too, we can observe bursts of jobs and of activity. We can also see the effect of September: the start of the new school year.

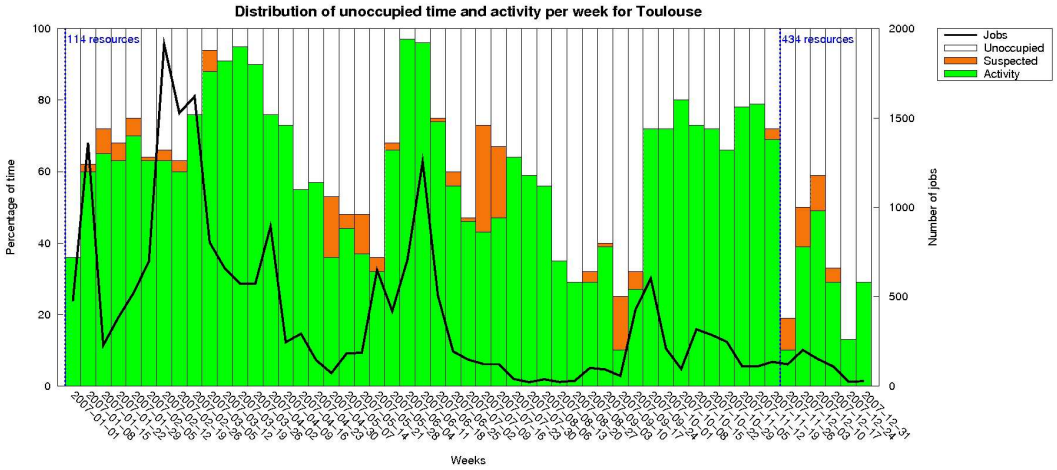

Figure 32: Global diagram without dead time for Grid'5000's Toulouse site

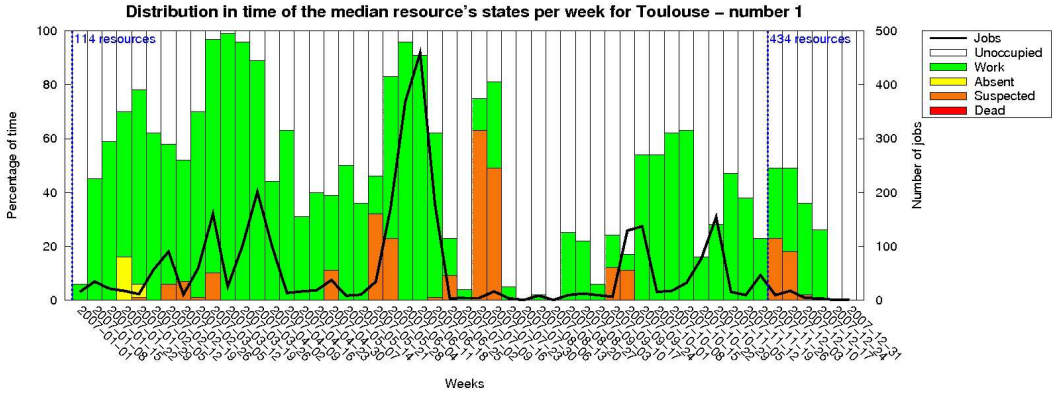

Figure 33: Median resource diagram for Grid'5000's Toulouse site

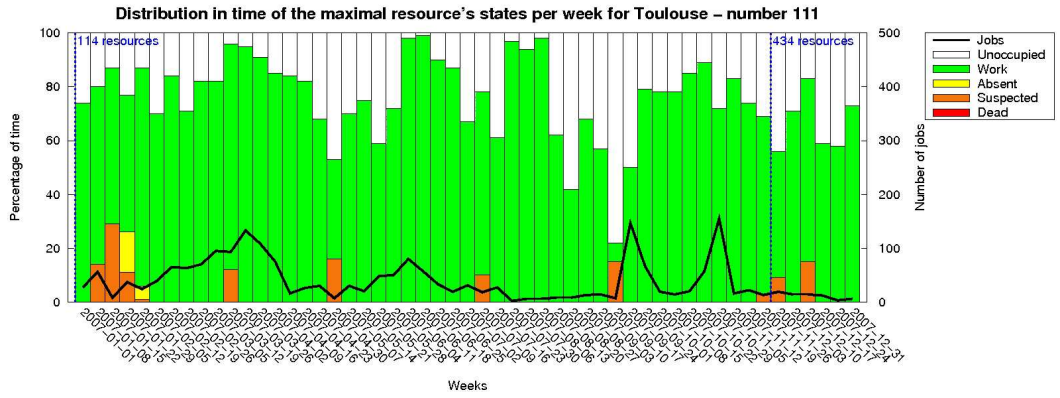

Figure 34: Maximal resource diagram for Grid'5000's Toulouse site

3.2.9 Results summary

Tables 1, 2, 3, summarize the main observed statistics:

- Platform and resources:

Site	Number of resources (cores)	Percentage of 'real' activity
Bordeaux	650	47.80%
Lille	250	36.44%
Lyon	322	46.38%
Nancy	574	56.41%
Orsay	684	18.88%
Rennes	714	49.87%
Sophia	568	51.43%
Toulouse	434	50.57%

Table 1: Resource-related statistics

- Jobs:

Site	Number of jobs (reservations)	Mean number of resources per job	Mean duration of a job in seconds	Jobs from other sites	'deploy' jobs
Bordeaux	45775	55.50	5224.59	0.53%	3.67%
Lille	330694	4.81	1446.13	0.08%	0.66%
Lyon	33315	41.64	3246.15	0.74%	8.07%
Nancy	63435	22.46	19480.49	0.16%	3.73%
Orsay	26448	47.45	4322.54	0.89%	16.81%
Rennes	36433	54.85	7973.39	0.90%	8.60%
Sophia	35179	57.93	4890.28	0.64%	7.31%
Toulouse	20832	12.89	7420.07	0.59%	3.93%

Table 2: Job-related statistics

- Users:

Site	Number of users	Users from other sites
Bordeaux	174	85.06%
Lille	181	74.59%
Lyon	147	71.43%
Nancy	154	83.12%
Orsay	189	81.48%
Rennes	194	81.96%
Sophia	183	81.97%
Toulouse	161	75.78%

Table 3: User-related statistics

4 A focus on Grid jobs

We have made some statistics on grid jobs where at least two jobs run on different sites with the same user and which have at least five minutes in common during their execution time. This means that a user has launched at least two jobs on at least two different sites and they are simultaneous for at least five minutes.

With this definition, we have looked for grid jobs in the traces used previously. For the same period (from the 1st January 2007 at 00:00:00 to the 6th January 2008 at 23:59:59), we have counted 208 different users who have launched grid jobs. The mean number of resources used per grid job is 57.69 and the mean duration of a grid job is 11922.76 seconds (3 hours 18 minutes and 42 seconds).

We have detailed these statistics per site:

These statistics vary from one site to another, but taken as a whole, the grid jobs use a lot of resources (60 in total average) and last a long time (more

Site	Mean number of resources per grid job	Mean duration of a grid job (sec.)
Bordeaux	64.07	15406.22
Lille	45.90	9674.48
Lyon	51.02	9396.19
Nancy	79.65	21082.16
Orsay	47.25	12494.29
Rennes	57.33	11772.41
Sophia	66.38	9082.74
Toulouse	34.64	9911.03

Table 4: Grid jobs statistics

than three hours in average) when compared to all the jobs, using the results presented in the previous paragraphs.

Figure 35 shows the number of computing hours by week and by site spent by the grid jobs. The first graph presents the grid jobs per site in hours for the histogram and in number for the black line. The red line shows the total number of work hours for all the sites per week. This red line is detailed per site on the second graph.

The second histogram shows the number of work hours per site and per week. The black line represents the total number of jobs per week. This gives a global view of the grid.

As in the previous statistics, the number of jobs is not directly correlated with the work time. We can see that the global proportion of grid jobs is important.

5 Conclusion

The Grid'5000 platform is an important framework for doing research on large-scale distributed systems. During year 2007, we have observed some bursts and gaps in Grid'5000's usage depending on the sites, timing effects (vacations), platform context (dead machines) and user locality.

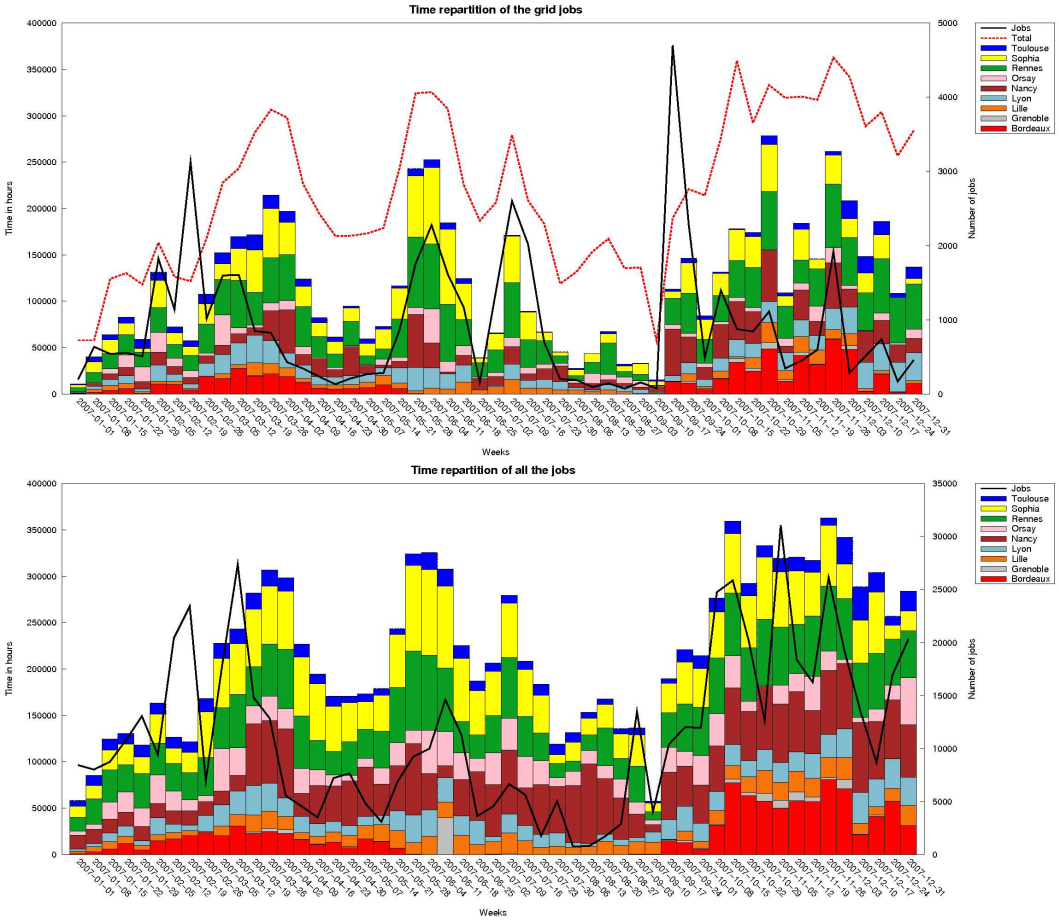

Figure 35: Computing hours of the grid jobs and of all the jobs per week and per site

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